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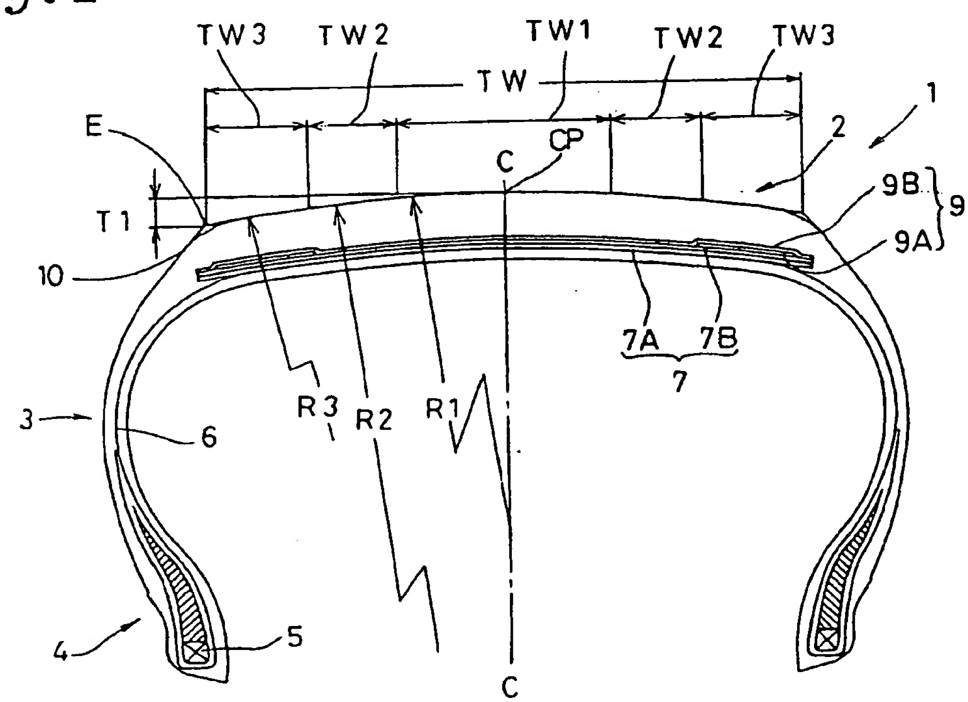
(54) Pneumatic radial tyre

(57) A pneumatic radial tyre has a tread profile comprising a curved crown part (TW1) having a radius of curvature R1, a pair of curved middle parts (TW2) having a radius of curvature R2 and a pair of curved shoulder parts (TW3) having a radius of curvature R3 which extend continuously without forming any inflection point, wherein the radius R1 is in the range of from 2.0 to 3.5 times the tread width TW and is less than the radius R2 and more than the radius R3, and the camber quantity T1 which is the radially distance of the tread edges from the tyre equator is 0.038 to 0.050 times the tread width TW, whereby noise generated from the tyre when going down a difference in road level is reduced.

Fig. 1



EP 0 790 142 A1

Description

The present invention relates to a pneumatic radial tyre which can reduce the noise generated from the tyre when going down a difference in road level.

As concrete roads age, the joints thereof are liable to have a relatively large difference in road level. For example, in a freeway in North America, as shown in Fig.5, a road level difference (x) of 5 to 8 mm repeats every joint span (y) of about 4.6 to 4.8 m. When automobiles go down such road level differences at high speed, the tyres generate an uncomfortable sound (hereinafter go-down noise) at short intervals and at a relatively high sound pressure level.

The frequency spectrum of such a pulsive go-down noise has three peaks at about 80, 250 and 750 Hz. If the individual pulsive sound is heard through a band-pass filter, the low-frequency noise of about 80 Hz sounds 'DON', the middle-frequency noise of about 250 Hz sounds 'HOU', and the high-frequency noise of about 750 Hz sounds 'PATA'.

In order to reduce the go-down noise, the present inventor made many attempts to change the natural vibration of the tyre by improving the internal structure of the tyre. However, when the sound pressure level at one peak was reduced, the others increases, and it was almost impossible to decrease all the peaks.

The present inventor therefore, made a close analysis of the causes of the go-down noise, and found that the noise sound level is greatly affected by not only the magnitude of the shock when the tyre contacts with the lower level road surface but also the flow speed of the air between the tyre tread and road surface when removed by the rotating tyre.

If a crown part of the tread has a relatively large radius of curvature, the tread has a tendency to contact with the road surface in its edges first and then the tread crown follows. And the change in the ground contacting area from the beginning to the end of the ground contacting occurs in a very short period. Thus, the sound level of the go-down noise is high.

On the other hand, if the tread crown part has a relatively small radius of curvature, the tread has a tendency to contact with the road surface in the tread crown part first and then the edge parts follow. And the change in the ground contacting area from the beginning to the end of the ground contacting is relatively slow, and the go-down noise level is low.

However, if the radius of curvature of the crown part is simply decreased, uneven wear of the tread portion such as heel-and-toe wear, polygonal wear and the like is liable to occur.

In Japanese laid-open patent application Nos. JP-A-4-87802 and JP-A-5-229308, a tyre having a tread profile defined by three radii of curvature has been disclosed, wherein the radius of curvature decreases from the crown part to the shoulder parts to improve the high speed steering stability. In such a profile however, the tyre suffers from uneven wear.

In contrast, Japanese laid-open patent application No. JP-A-6-297912 disclose a motorcycle tyre having a tread profile defined by three radii of curvature, wherein the three radii are set to be larger in the shoulder parts than the crown part and to be minimum in the middle parts so as to improve the cornering performance. This profile can not be applied to a tyre for four-wheel vehicles because it is designed for a motorcycle tyre. In other words, a motorcycle tyre is not intended in the present invention.

It is therefore, an object of the present invention to provide a pneumatic radial tyre in which the go-down noise is reduced without increasing the uneven wear.

According to one aspect of the present invention, a pneumatic radial tyre comprises a tread portion, a pair of sidewall portions, a pair of bead portions, a pair of bead cores one disposed in each of the bead portions, a carcass extending between the bead portions through the tread portion and sidewall portions and turned up around the bead cores to be secured thereto, and a belt disposed radially outside the carcass and inside the tread portion, the tread portion having a profile comprising a curved crown part having a radius of curvature R1 and extending from the tyre equator toward both sides thereof, a pair of curved middle parts having a radius of curvature R2 and each having an axial inner edge which is connected to one of the axial edges of the curved crown part without forming any inflection point therebetween, and a pair of curved shoulder parts having a radius of curvature R3 and each having an axial inner edge which is connected to the axial outer edge of one of curved middle parts without forming any inflection point therebetween, each of the shoulder parts extending to just or near the axially outermost edge of the ground contacting region, wherein the radius of curvature R1 of the curved crown part is in the range of from 2.0 to 3.5 times the tread width TW and is less than the radius of curvature R2 of the curved middle parts and more than the radius of curvature R3 of the curved shoulder parts, ($R3 < R1 < R2$) and the camber quantity T1 which is the radial distance of the tread edges from the tyre equator is 0.038 to 0.050 times the tread width TW.

Here, the tread profile is defined as in a tyre meridian section including the tyre axis under an unloaded state in which the tyre is mounted on a standard rim and inflated to a standard pressure and loaded with no tyre load.

The standard rim, the standard pressure and standard load are those specified in a standard such as JATMA (Japan), TRA (USA), ETRTO (Europe) and the like for measuring the tyre.

Preferably, the radius R2 of the middle parts is 5.0 to 7.0 times the tread width TW, and the radius R3 of the shoulder

parts is 0.8 to 1.8 times the tread width TW.

Preferably, the axial width TW1 of the crown part is in the range of from 25 to 40% of the tread width TW, and the axial width TW2 of each of the middle parts is in the range of from 13 to 18% of the tread width TW, and the axial width TW3 of each of the shoulder parts is in the range of from 13 to 18% of the tread width TW.

An embodiment of the present invention will now be described, by way of example only, in detail in conjunction with the accompanying drawings, in which:

Fig.1 is a cross sectional view of an embodiment of the present invention;
Fig.2 shows an example of the tread pattern used in this embodiment;
Fig.3 is a schematic cross sectional view showing a square shoulder;
Fig.4 is a schematic cross sectional view showing a round shoulder;
Fig.5 is a schematic cross sectional view explaining difference in road level; and
Fig.6 is a schematic cross sectional view showing a wear energy measuring device.

In Fig.1, a pneumatic radial tyre 1 according to the present invention comprises a tread portion 2, a pair of axially spaced bead portions 4, a pair of sidewall portions 3 extending between tread edges E and the bead portions 4, a pair of bead cores 5 are disposed in each of the bead portions 4, a carcass 6 extending between the bead portions 4 through the tread portion 2 and sidewall portions 3 and tumed up around the bead cores 5 to be secured thereto, and a belt disposed radially outside the carcass and inside the tread.

The tyre 1 is a tyre for passenger cars having an aspect ratio of not more than 0.8. (Tyre size: 195/65R15, Aspect ratio: 0.65)

The carcass 6 comprises at least one ply, in this embodiment only one ply, of cords arranged radially at an angle of from 90 to 75 degrees with respect to the tyre equator C.

For the carcass cords, organic fibre cords, e.g. polyester, nylon, rayon and the like are preferably used. However, steel cords may be used depending on the use of the tyre.

The belt in this example comprises a breaker 7 disposed on the radially outside of the carcass and a bandage 9 disposed radially outside the breaker 7.

The breaker 7 is composed of at least two plies 7A and 7B each made of parallel cords laid at an angle of from 15 to 30 degrees to the tyre equator C so as to cross the cords of the next ply.

For the breaker cords, steel cords are preferably used, but organic fibre cords, e.g. aramid, nylon, polyester, rayon and the like can be used.

The bandage 9 is made of one or more organic fibre cords laid substantially parallel to the circumferential direction of the tyre.

In this example, the bandage 9 is composed of a full-width band 9B and a pair of axially spaced edge bands 9A.

The full-width band 9B is disposed on the radially outside of the breaker 7 and extends all over the width thereof so as to cover the radially outside of the breaker 7.

The edge bands 9A are disposed on the radially outside of the full-width band 9B so as to cover only the breaker edge portions.

For the band cords, nylon cords are used in this example, but polyester, rayon, aromatic polyamide may be used.

The tread portion 2 is provided with a tread profile comprising curved parts TW1, TW2 and TW3 having different radii R1, R2 and R3 of curvature.

A crown part TW1 which has a radius of curvature R1 extends from the tyre equator CP toward both sides thereof.

A pair of middle parts TW2 which have a radius of curvature R2 extend axially outwardly from the axial edges of the crown part.

A pair of shoulder parts TW3 which have a radius of curvature R3 extend axially outwardly from the axial outer edges of the middle parts to the axial outermost edge of the ground contacting area.

These parts are connected to each other without forming any inflection point.

The radius of curvature R1 of the crown part is set to be less than the radius of curvature R2 of the middle parts and more than the radius of curvature R3 of the shoulder parts. ($R3 < R1 < R2$)

The radius of curvature Rl of the crown part is set in the range of from 2.0 to 3.5 times the tread width TW, more preferably 2.0 to 3.0 times, still more preferably 2.0 to 2.7 times TW. Such radius R1 is very small in a passenger tyre.

If the radius R1 is more than 3.5 times TW, the go-down noise is not reduced. If the radius R1 is less than 2.0 times TW, the ground pressure in the crown part becomes higher than the other parts and the crown part wear is accelerated.

Further, the camber quantity T1 which is the radial distance between the tyre equator CP and tread edge E is set in the range of from 0.038 to 0.050 times the tread width TW so as to minimise variation of the tyre diameter in the ground contacting region.

If the camber quantity T1 is more than 0.050 times the tread width TW, uneven wear such as heel/toe wear of

tread elements (blocks) increases. If the camber quantity T1 is less than 0.038 times TW, noise becomes worse.

Such a small camber quantity is realised by the contribution of the middle parts whose radius R2 is largest in the three parts. As a result, uneven wear can be prevented.

Owing to the combination of the very small radius R1 of the crown part, the relationship R2 > R1 > R3, and the specifically limited camber quantity T1, when going town the road, the crown part contacts the road surface first and the ground contacting area gradually increases. As a result, the go-down noise can be reduced, and further uneven wear of the tread rubber can be decreased.

The axial width TW1 of the crown part is set in the range of from 25 to 55 %, more preferably 30 to 40 % of the tread width TW.

If TW1 is less than 25% TW, the crown part can not display its function and the ground contacting behaviour is not gradual. If TW1 is more than 45% TW, it becomes difficult to set the camber quantity T1 at a small value, and uneven wear is liable to occur.

In order to limit the camber quantity T1 in the above-mentioned range and to make the going-down behaviour change gradual with controlling the uneven wear, the radius of curvature R2 of the middle parts is set in the range of from 5.0 to 7.5 times, preferably 5.3 to 7.0 times, more preferably 5.3 to 6.7 times the tread width TW, and the axial width TW2 of the middle parts is preferably set in the range of from 13 to 18 % of the tread width TW.

In order to smoothly discharge the air existing between the tyre and the road surface towards the axially outsides of the tyre, the radius of curvature R3 of the shoulder parts is set in the range of from 0.8 to 1.8 times, preferably 1.0 to 1.4 times the tread width TW, and the axial width TW3 of the shoulder parts is preferably set in the range of from 13 to 18 % of the tread width TW.

If the ratio R2/TW is set in the range of from 0.8 to 1.8 and the ratio R3/TW in the range of from 5.0 to 7.5, it is possible to set the ratio T1/TW in the range of from 0.038 to 0.050. In this case, however, the air discharge is not gradual, and the noise can not be reduced. Further, as the middle parts between the crown part and the shoulder parts have a smaller radius of curvature, the steering stability especially at a transitional stage of cornering is lowered.

The above-mentioned tread width TW is the axial width of the tread portion 2.

In a square shoulder having angled tread edges E as shown in Fig.3, the tread width TW is defined between the angled tread edges E.

In this case, the shoulder part of the radius R3 extends to the tread edge E which may be the axial outermost edge (e1) of the ground contacting area.

In a round shoulder as shown in Fig.4, the tread width TW is defined between imaginary tread edges E. As being well known in the art, the imaginary tread edge E is a intersecting point of an extended line of the shoulder part profile line and an extended line of the profile line of the buttress part 10 (upper sidewall part).

In this case, the radius of curvature R4 of the rounded tread edge part is set to be less than the radius of curvature R3 and to be not more than 0.5 times, more preferably 0.3 times the tread width TW. If the ratio R4/TW is more than 0.5, the ground contacting width decreases, and the steering stability and wear resistance are liable to become worse.

The rounded edge part is connected to the axially outer edge (a) of the shoulder part without forming any inflection point therebetween, whereby the axial outermost edge (e2) of the ground contacting area may be axially outwards of the axially outer edge (a) of the shoulder part.

The axial distance SW between the imaginary tread edge E and the axially outer edge (a) is preferably set in the range of not more than 0.5 times, more preferably not more than 0.4 times the axial width TW3 of the shoulder part. If the SW/TW3 ratio is more than 0.5 times, the ground contacting width decreases to deteriorate the steering stability and wear resistance.

The ground contact area is defined as of the tyre when mounted on the standard rim and inflated to the standard inner pressure and loaded with the standard tyre load.

Comparison Tests

Test tyres of size 195/65R15 were made be way of test. The test tyres were provided with the same tread pattern shown in Fig.2 but various profiles by hand cutting slick tyres.

In the tread pattern of Fig.2, a central wide circumferential groove 15 extends along the tyre equator, a pair of wide circumferential grooves 13 are disposed immediately outside the boundary of the crown part TW1 and middle parts TW2 within a 10 mm range from the boundary, a pair of narrow circumferential grooves 14 are also disposed immediately outside the boundary of the middle parts TW2 and shoulder parts TW3 within a 10 mm range from the boundary.

The test tyres were tested for go-down noise and uneven wear.

(1) Go-down noise test

Running on Bakersfield Freeway #99 in California USA, the maximum sound pressure level of the go-down noise

at a running speed of 60 mph was measured in a low-frequency band (40 to 100Hz), middle-frequency band (200 to 260Hz) and high-frequency blind (600 to 860Hz), using a microphone set near the headrest of the driver's seat.

Test car:	HONDA ACCORD LX
Wheel Rim:	15X5.5JJ
Air pressure:	Front 2.2 kgf/cm^2
	Rear 2.2 kgf/cm^2

(2) Uneven wear test

Using a wear energy measuring device made up of a triaxial stress sensor 11 having strain gauges G and a slip sensor 12 as shown in Fig.6, the ground pressure and the amount of slip was measured, from which the wear energy at many points CR in the crown part, MD in the middle parts, SF, SM, SR in the shoulder parts as shown in Fig.2 was obtained by means of calculation.

The wear energy can be obtained by integrating the product (PXS) of the ground pressure P and the amount of slip S from entering the ground contacting area to leaving it.

When the wear energy is even at the measuring points SF, SM and SR, especially SF and SR, the heel and toe wear decreases.

When the wear energy is even between the points CR and MD, uneven wear in the tyre axial direction such as crown wear and shoulder wear is decreased.

The tyre load in the vertical direction was 450 kgf. The slip angle was zero and the camber angle was also zero.

The test results are shown in Table 1.

From the test results, it was confirmed that, in comparison with the reference tyre 2, the example tyres 1, 2 and 3 were improved in the peak sound level at about 80, 250 and 750 Hz of the go-down noise, and at the same time the wear energy was evened out in both the axial and circumferential directions.

Further, as the air between the tread and road surface can be smoothly discharged, the water existing between the tread and road surface is also discharged effectively. Thus the tyres according to the present invention are also superior in the aquaplaning performance.

Table 1

Test Tire	Ex. 1	Ex. 2	Ex. 3	Ref.1	Ref.2	Ref.3	Ref.4	Ref. 5
Crown part								
Radius R1 (mm)	450	300	525	250	800	300	525	525
Width TW1 (mm)	50	50	50	50	50	-	-	50
R1/TW	3.0	2.0	3.5	1.7	5.3	2.0	3.5	3.5
TW1/TW	0.33	0.33	0.33	0.33	0.33	-	-	0.33
Middle part								
Radius R2 (mm)	800	1000	800	800	800	300	525	400
Width TW2 (mm)	25	25	25	25	25	-	-	25
R2/TW	5.3	6.7	5.3	5.3	5.3	2.0	3.5	2.7
TW2/TW	0.16	0.16	0.16	0.16	0.16	-	-	0.16
Shoulder part								
Radius R3 (mm)	150	260	200	200	200	300	525	800
Width TW3 (mm)	25	25	25	25	25	-	-	25
R3/TW	1.0	1.7	1.3	1.3	1.3	2.0	3.5	5.3
TW3/TW	0.16	0.16	0.16	0.16	0.16	-	-	0.16
Tread edge								
Radius R4 (mm)	20	20	20	20	20	20	20	20
R4/TW	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Camber T1 (mm)	6.5	7.5	5.7	9.1	4.7	9.5	5.4	5.7
T1/TW	0.043	0.050	0.038	0.061	0.031	0.063	0.036	0.038

Table 1 (continued)

Test Tire	Ex. 1	Ex. 2	Ex. 3	Ref.1	Ref.2	Ref.3	Ref.4	Ref. 5
Noise level (dB)								
Low-freq.	63.9	63.2	65.3	63.0	66.5	63.7	66.9	66.8
Middle-freq.	67.2	66.1	68.1	66.0	68.3	66.5	68.4	68.3
High-freq.	61.2	59.7	62.3	59.1	63.5	59.8	63.9	64.3
Wear energy (kgf·mm/sq.cm)								
Point Cr	0.39	0.44	0.37	0.60	0.29	0.49	0.36	0.35
Point MD	0.37	0.36	0.39	0.31	0.43	0.20	0.27	0.19
Point SF	0.30	0.28	0.32	0.15	0.19	0.31	0.52	0.49
Point SM	0.33	0.32	0.34	0.22	0.21	0.48	0.61	0.67
Point SR	0.39	0.40	0.38	0.42	0.25	0.72	0.69	0.78
Maximum	0.39	0.44	0.39	0.60	0.43	0.72	0.69	0.78
Minimum	0.30	0.28	0.32	0.15	0.19	0.20	0.27	0.19
Difference	0.09	0.16	0.07	0.45	0.24	0.52	0.42	0.59
Tread width TW = 150 mm Ground contacting width = 136 mm								

Claims

1. A pneumatic radial tyre comprising a carcass (6) extending between bead portions (4) through a tread portion (2) and sidewall portions (3) and a belt disposed radially outside the carcass (6) and inside the tread portion (2), characterised in that the tread portion (2) has a profile comprising a curved crown part having a radius of curvature R1 and extending from the tyre equator (CP) toward both sides thereof, a pair of curved middle parts (TW2) having a radius of curvature R2 and each having an axial inner edge which is connected to one of the axial edges of the curved crown part (TW) without forming any inflection point therebetween, and a pair of curved shoulder parts (TW2) having a radius of curvature R3 and each having an axial inner edge which is connected to the axial outer edge of one of curved middle parts without forming any inflection point therebetween, each of the shoulder parts extending to just or near the axially outermost edge of the ground contacting region, wherein the radius of curvature R1 of the curved crown part (TW) is in the range of from 2.0 to 3.5 times the tread width TW and is less than the radius of curvature R2 of the curved middle parts (TW2) and more than the radius of curvature R3 of the curved shoulder parts (TW3), and the camber quantity T1 which is the radial distance of the tread edges from the tyre equator (CP) is 0.038 to 0.050 times the tread width TW.

2. A pneumatic radial tyre according to claim 1, characterised in that the radius R2 of the middle parts (TW2) is 5.0 to 7.0 times the tread width TW, and the radius R3 of the shoulder parts (TW3) is 0.8 to 1.8 times the tread width TW.

3. A pneumatic radial tyre according to claim 1 or 2, characterised in that the axial width TW1 of the crown part is in the range of from 25 to 40% of the tread width TW, and the axial width TW2 of each of the middle parts is in the range of from 13 to 18% of the tread width TW, and the axial width TW3 of each of the shoulder parts is in the range of from 13 to 18% of the tread width TW.

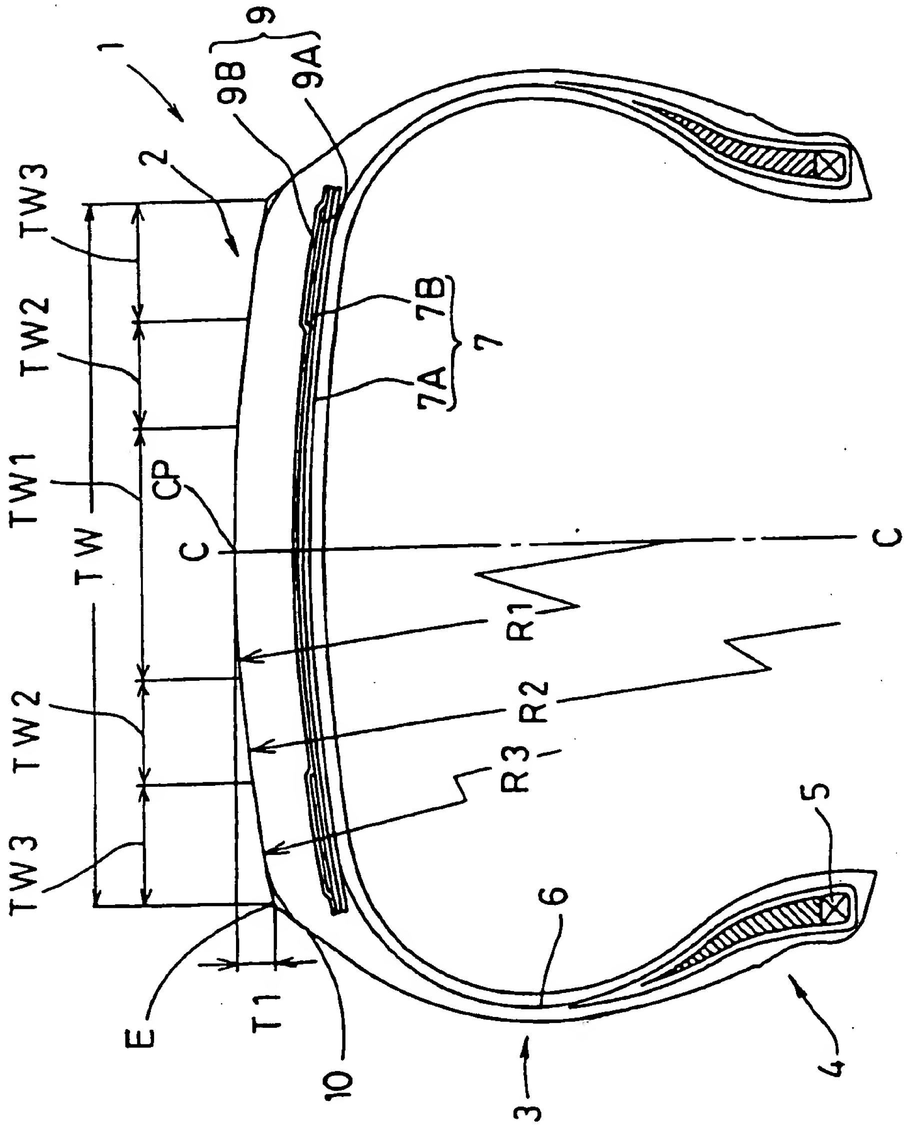


Fig. 1

Fig. 2

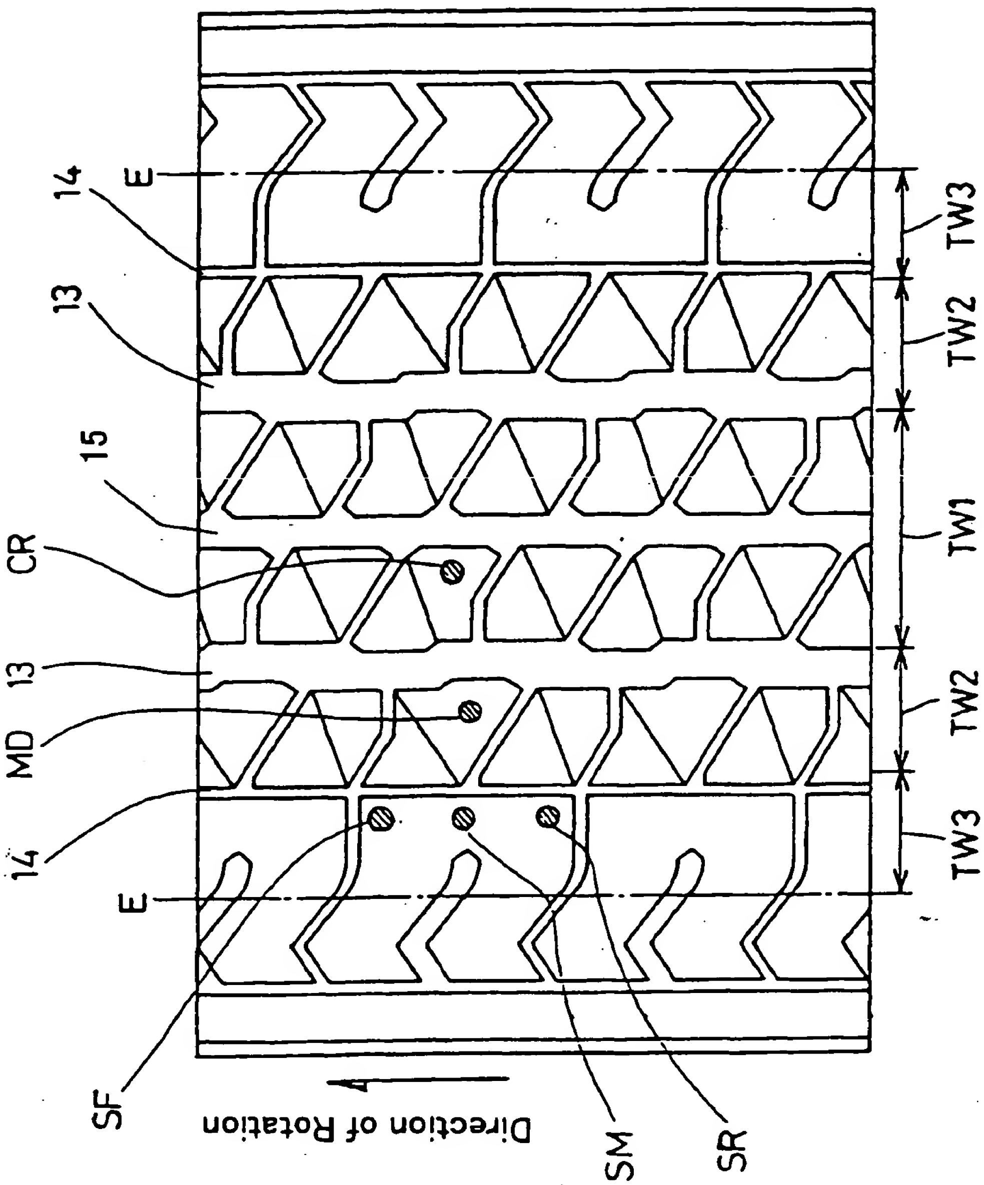

14
13
15
CR
13
MD
14
E
E
TW3
TW2
TW1
TW2
TW3
SF
SM
SR
Direction of Rotation

Fig.3

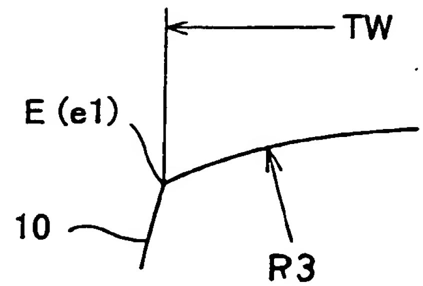


Fig.4

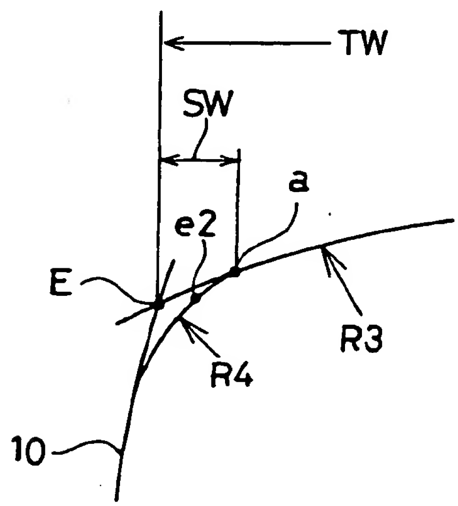
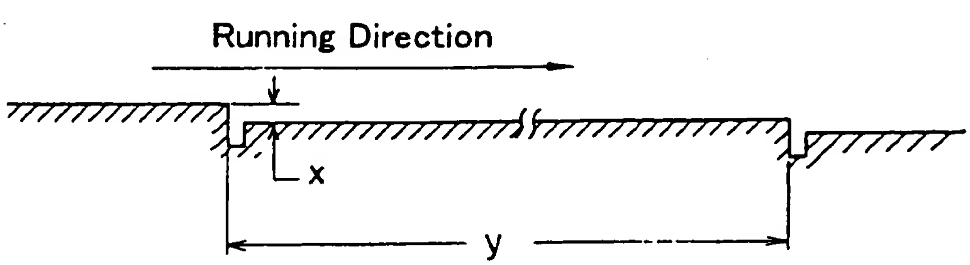


Fig.5



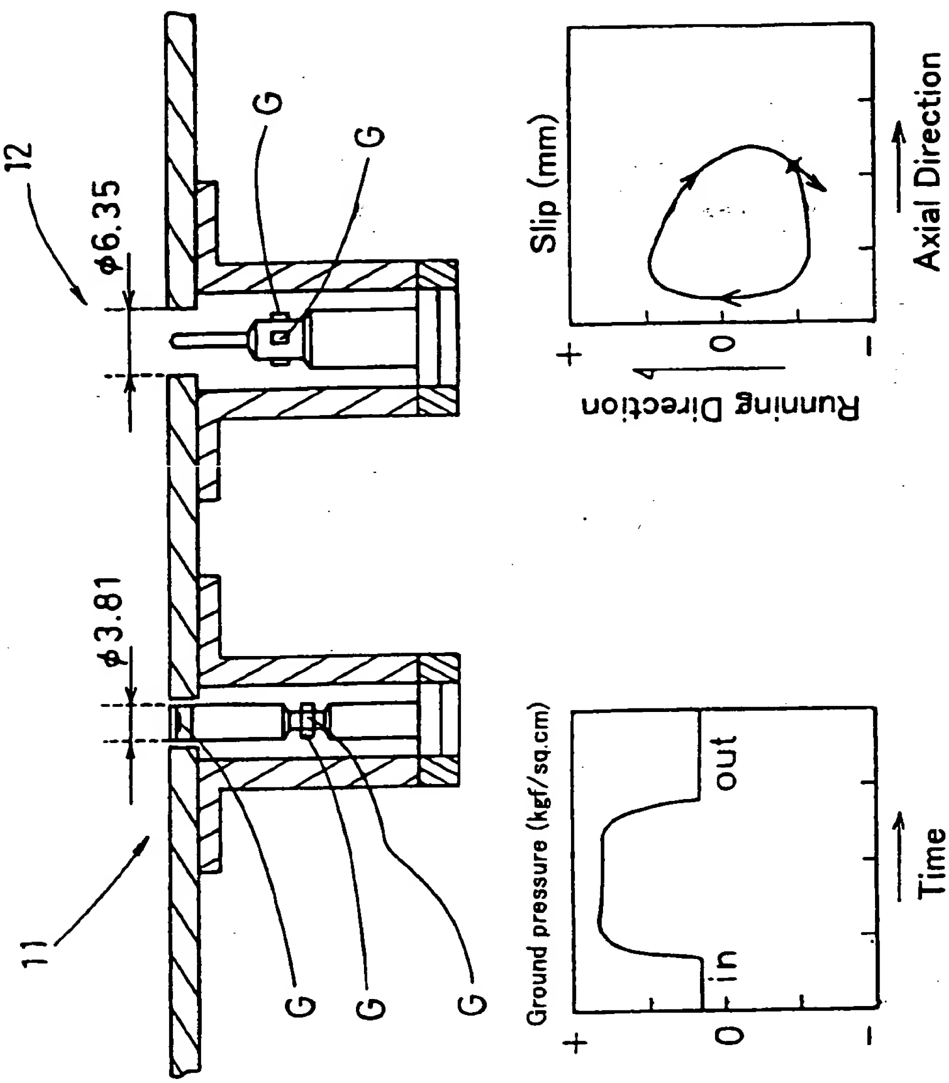

11
12
φ3.81
φ6.35
G
G
G
G
G
Ground pressure (kgf/sq.cm)
+
0
-
in
out
Time
Slip (mm)
Running Direction
Axial Direction

Fig.6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 0884

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	PATENT ABSTRACTS OF JAPAN vol. 12, no. 183 (M-703), 28 May 1988 & JP 62 295702 A (SUMITOMO RUBBER IND LTD), 23 December 1987, * abstract *	1-3	B60C3/04 B60C11/00 B60C11/01
Y	EP 0 477 542 A (THE GOODYEAR TIRE AND RUBBER COMPANY) * column 6, line 31 - column 7, line 9; claim 1 *	1-3	
A	EP 0 402 303 A (THE GOODYEAR TIRE AND RUBBER COMPANY) * page 3, line 35 - line 52; figure 4 *	1-3	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			B60C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 April 1997	Reedijk, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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